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Controlling Downstream Particle Segregation with a Twisted Standpipe

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Abstract - When designing handling plant for directing the bulk solids into downstream processes it is often a requirement that the natural segregation of particles be minimised.

This paper reports on a model study where, instead of trying to eliminate segregation, it was controlled by employing a square standpipe with a helical twist down the axis of the standpipe. A summary of the outcomes is provided where it was shown that it is possible to control the flow of a bulk solid down a vertical choked flow standpipe by inducing a helical twist in the standpipe and hence providing a positive influence on the downstream segregation issues.

1. INTRODUCTION

When designing handling plant for directing the bulk solids into downstream processes it is often a requirement that the natural segregation of particles be minimised. This is especially a requirement when the downstream flow is to be split into separate streams and/or evenly spread across processing equipment. While minimising particle segregation can often be achieved with well designed handling equipment, it may be impossible to achieve in plant that already exists without radical plant modifications being undertaken. However, in such situations it may be possible to control the particle segregation and hence minimise the resulting ill-effects.

Arising out of the requirement to control the segregation of coal being fed from a hopper to the stokers in a coal-fired ship, a model study was undertaken employing a square standpipe with a helical twist down the axis of the standpipe. The aim of twisting the standpipe was not to eliminate segregation but control the segregation by rotating the flow of coal so that the streams being divided and presented to the stokers were less prone to problems arising from particle segregation. The study was undertaken using a laboratory scale test rig with a standpipe capable of producing a twist of up to 105° over the one metre length of the standpipe.

This paper highlights the extent of this preliminary model study and provides a summary of the outcomes where it was shown that it is possible to control the flow of a bulk solid down a vertical choked flow standpipe of square cross-section by inducing a helical twist in the standpipe and hence to provide a positive influence on the downstream segregation issues.

2. TEST RIG CONFIGURATION

The laboratory scale test rig comprised a square Perspex tube (overall length approximately 1000 mm, side width approximately 100 mm), with the tube sides and rig design having the flexibility to absorb a degree of helical twisting about the central axis.

The square tube was mounted in a frame that provided horizontal supports at 200 mm intervals over a 1 m total length. timber disks were located centrally on each of these levels. A simple bolt and clamping arrangement around the perimeter allowed the timber disks to be incrementally rotated and fixed in position, hence inducing a twist in the Perspex tube. Figure 1 shows the actual test rig, with a helical twist imposed on the tube. The extent of the twist that could be achieved in this manner was limited by the flexibility of the Perspex and the clearance in the square holes in the timber disks. The timber disks, apart from allowing the rate of twist to be controlled with some precision, helped ensure that the tube maintained a basically square cross section from top to bottom, despite the twisting action applied to it and ensuring that the cross-sectional area available to flow was maintained down the standpipe.

Material was fed into the tube from a conical hopper, with an appropriate outlet dimension (matching the 100×100 mm tube cross-section). A partition was provided in this hopper to allow different materials to be fed into

each side. In this way a segregated material could be fed into the Perspex tube, and the capacity of the twist in the tube to maintain and rotate this segregated material, easily evaluated. Figure 2 shows a top view of this hopper, with the partition evident. The white material shown is plastic pellets, the black material is canola seed, both are free flowing spheroidal shaped particles, of similar particle density and loose poured bulk density, but different size.



Figure 1 Test Rig with Approximately 90° Twist Imposed on the Perspex Tube



Figure 2 Top View of Feeding Hopper Showing the Partition Separating the Feed Materials

Material was withdrawn from the hopper via a vibrating feeder (Figure 3). The magnitude and rate of vibration of this feeder could be adjusted to control the rate of discharge from the tube.



Figure 3 Vibrating feeder

3. TEST MATERIALS

Three bulk materials were used in the trials. They were free flowing bulk materials, so that it would be unlikely that internal arching obstructions would be formed in the chute. Each material was predominantly mono-sized, however, there was a substantial variation in particle size between the three materials. This allowed a segregation based on particle size to be prepared for the tests, as well as allowing the materials to be separated after each run. The materials were also visually distinct, assisting in identifying the effectiveness of the flow control being applied by the twisted standpipe. Table 1 lists the materials and some of their basic properties.

Table 1 Test Material Properties

Bulk Material	Plastic Pellets	Canola Seed	Alumina Hydrate
Particle size	$d_v \approx 5 \text{ mm}$	$\approx 1 \text{ mm}$	$D_{50} = 95 \text{ }\mu\text{m}$
Particle shape	Rounded disk	Spheroid	Irregular, rounded
Particle density (ρ_s)	918 kg/m^3	1166 kg/m^3	2470 kg/m^3
Bulk density (loose poured ρ_{BL})	565 kg/m^3	660.7 kg/m^3	1020 kg/m^3
Colour	white	black	white

4. TEST RESULTS

The twist potential of the test rig was determined by locking the bottom disk, and progressively twisting and locking the adjacent higher disk. In the initial configuration, a total twist of 80° could be induced in the standpipe in this manner. The test rig was then placed over the vibrating feeder, and filled with white plastic pellets. The hopper above the standpipe was then loaded with plastic pellets (white) on one side of the divider, and canola seed (black) on the other, as shown in Figure 2. The vibrating feeder was then activated, and the bulk material drawn through the standpipe in a "choked flow" condition. As the black canola seed emerged from the hopper and became visible in the Perspex standpipe section it was clear that the bulk materials were indeed following the twist imposed by the standpipe, rotating as a bulk following essentially the same helical path. Figure 4 depicts the typical flow pattern development observed within the standpipe. In this figure the white material is plastic pellets and the black is canola seed.

The general conclusion from these tests is that the material flow down the twisted standpipe retained the initial segregation pattern prevalent at the entry point of the tube, but rotated this segregation pattern in line with the rotation of the helical twist in the standpipe. If the orientation of the feed materials was arranged appropriately,

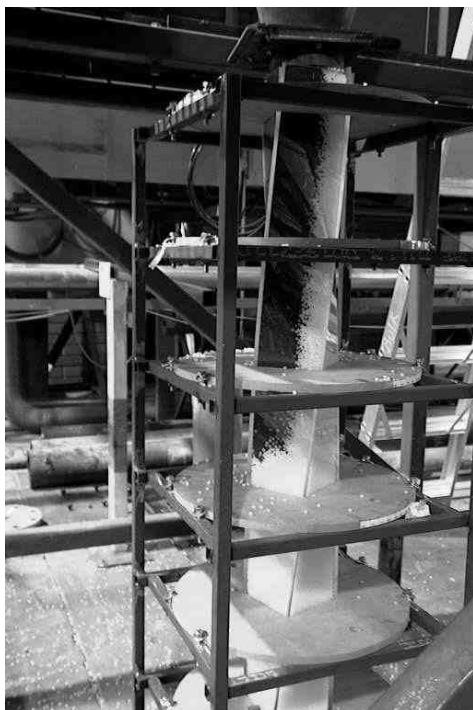
the maintenance of the segregation pattern can be clearly seen on the bed of the vibrating feeder, as shown in Figures 5 and 6.



(a)



(b)



(c)



(d)

Figure 4 Flow Pattern Development within Standpipe



Figure 5 Top View of Segregated Materials (Plastic Pellets and Canola Seed) Being Discharged from Twisted Standpipe



Figure 6 End View of Segregated Materials (Alumina Hydrate [White Material] and Canola Seed) Being Discharged from Twisted Standpipe

As noted earlier in this section, the initial twist capacity of the test rig was 80° over the 1 m spacing between the bottom and top timber disks. By chamfering the square holes in the timber disks (and hence increasing the clearance available to the Perspex sheets during the twisting operation) it was possible to increase the twist up to 105° . Additional trials were conducted with the standpipe twisted at 90° and 105° to evaluate the operation of the rig under conditions of increased twist. In each case the visual indication was that the bulk solids continued to follow the helical path imposed by the twisted chute. The same outcome was observed when the plastic pellets were replaced by the white alumina hydrate (as shown in Figure 6).

When a standpipe is twisted in the manner described in this paper, the degree of rotation could be specified in terms of the relative rotation of two horizontal sections of the standpipe (for example, a 90° twist between two sections separated by 1m), or in terms of the "helix" angle. The helix angle is the angle that would be observed between one of the diagonal corners of the chute and the vertical axis, when the standpipe is viewed from the side.

In this series of tests, the maximum relative rotation between the two end timber disks was 105°. For a square cross-section chute with an inside side dimension of 100mm, this corresponds a diagonal length of 141mm, and a helix angle of 7.4°.

5. CONCLUDING REMARKS

This investigation has demonstrated that it is possible to control the flow of a bulk solid down a vertical choked flow square cross-section standpipe by inducing a helical twist in the standpipe. This was achieved in a laboratory scale test rig capable of producing a twist of up to 105° over a 1 m length of standpipe. There appeared to be minimal (if any) lag in the bulk solids rotating at a slower rate than the helical twist in the standpipe walls. In this respect it appears that the bulk solids flowed through the twisted standpipe with minimal (if any) internal shear. For this behaviour to prevail it is important that the wall friction between the bulk solid and the standpipe wall is significantly less than the internal friction within the bulk solids.

There are a number of areas that may need to be considered in adapting this concept to a full-scale application. These are likely to include:

- Scaling up to larger standpipes - the helix angle variation that may be tolerable.
- The cohesive properties of the bulk material being handled – the necessity to modify the corner regions of the standpipe by radiusing or filleting corners.
- Standpipe design - maintaining or increasing the cross-sectional area in the direction of material flow.
- Friction and wear on standpipe walls.

Even though it is rather preliminary, this study has shown that employing a twisted standpipe it is possible to control segregation (rather than attempting to eliminate the segregation) by rotating the choked flow of bulk solids as they pass through the standpipe so that the streams being presented to downstream equipment are less prone to problems arising from particle segregation.